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Patentanmeldung Nr. Patent application No. Demande de brevet n°

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Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
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Particle shields for use in lithographic projection apparatus

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PARTICLE SHIELDS FOR USE IN LITHOGRAPHIC PROJECTION APPARATUS

The present invention relates to particle shields, e.g. for preventing contaminant particles from reaching a mask. More particularly, the invention relates to the application of such particle shields in lithographic projection apparatus comprising:

an illumination system constructed and arranged to supply a projection beam of radiation;

a first object table constructed to hold a mask;

a second object table constructed to hold a substrate; and

a projection system constructed and arranged to image an irradiated portion of the mask onto a target portion of the substrate.

For the sake of simplicity, the projection system may hereinafter be referred to as the "lens"; however, this term should be broadly interpreted as encompassing various types of projection system, including refractive optics, reflective optics, catadioptric systems, and charged particle optics, for example. In addition, the first and second object tables may be referred to as the "mask table" and the "substrate table", respectively. Further, the lithographic apparatus may be of a type having two or more mask tables and/or two or more substrate tables. In such "multiple stage" devices the additional tables may be used in parallel, or preparatory steps may be carried out on one or more stages while one or more other stages are being used for exposures. Twin stage lithographic apparatus are described in International Patent Applications WO 98/28665 and WO 98/40791, for example.

Lithographic projection apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In such a case, the mask (reticle) may contain a circuit pattern corresponding to an individual layer of the IC, and this pattern can be imaged onto a target area (comprising one or more dies) on a substrate (silicon wafer) which has been coated with a layer of radiation-sensitive material (resist). In general, a single wafer will contain a whole network of adjacent target areas which are successively irradiated via the mask, one at a time. In one type of lithographic projection apparatus, each target area is irradiated by exposing the entire mask pattern onto the target area in one go; such an apparatus is commonly referred to as a wafer stepper. In an alternative apparatus, which is commonly referred to as a step-and-scan apparatus,

each target area is irradiated by progressively scanning the reticle pattern under the projection beam in a given reference direction (the "scanning" direction) while synchronously scanning the substrate table parallel or anti-parallel to this direction; since, in general, the projection system will have a magnification factor M (generally < 1), the speed V at which the substrate table is scanned will be a factor M times that at which the mask table is scanned. More information with regard to lithographic devices as here described can be gleaned from International Patent Application WO 97/33205.

In a lithographic apparatus, the size of features that can be imaged onto the substrate is limited by the wavelength of the projection radiation. To produce integrated circuits with a higher density of devices, and hence higher operating speeds, it is desirable to be able to image smaller features. Whilst most current lithographic projection apparatus employ ultraviolet light generated by mercury lamps or excimer lasers, it has been proposed to use shorter wavelength radiation of around 13nm. Such radiation is termed extreme ultraviolet (EUV) or soft x-ray and possible sources include laser-produced plasma sources, discharge plasma sources or synchrotron radiation from electron storage rings. An outline design of a lithographic projection apparatus using synchrotron radiation is described in "Synchrotron radiation sources and condensers for projection x-ray lithography", JB Murphy et al, Applied Optics Vol. 32 No. 24 pp 6920-6929 (1993). So-called "undulators" and "wigglers" have been proposed as an alternative source of extreme ultraviolet radiation. In these devices, a beam of electrons traveling at high, usually relativistic, speeds, e.g. in a storage ring, is caused to traverse a series of regions in which magnetic fields perpendicular to the beam velocity are established. The directions of the magnetic field in adjacent regions are mutually opposite, so that the electrons follow an undulating path. The transverse accelerations of the electrons following the undulating path cause the emission of Maxwell radiation perpendicular to the direction of the accelerations, i.e. in the direction of the non-deviated path.

In a lithographic projection apparatus, it is necessary to prevent any stray particles that may be present in the apparatus from reaching, and becoming stuck to, the mask as they will then be imaged on the substrate and can be printed in the final device. Too high a level of contamination of the mask can lead to defective devices and the masks cannot generally be cleaned, or if cleanable can only be cleaned a limited number of times. In a lithographic projection apparatus using relatively long wavelength ultraviolet radiation, particles are prevented from reaching the mask by a pellicle. A pellicle is a thin membrane transparent to the radiation used in the projection beam of the lithographic apparatus and located parallel to but spaced from the mask. Contaminant particles moving towards the mask contact and stick to the pellicle. To

ensure that the particles stuck to the pellicle are not printed on the substrate, the pellicle is spaced from the mask by a distance greater than the depth of focus at mask level.

However, it is not at present possible to provide a pellicle in a lithographic projection apparatus using UV radiation of 193 nm or 157 nm or extreme ultraviolet radiation for the exposure beam. Almost all materials are strongly absorbative of EUV radiation and a conventional membrane pellicle would have to be no more than about 30nm thick in order not to cause unacceptable absorption of the projection beam. A membrane of this thickness would not have a sufficient lifetime in both a vacuum, during operation of the apparatus, and atmospheric environment, during installation and service. Other stresses, such as optical stress and temperature variance would also likely destroy such a thin membrane very quickly.

An alternative approach to a separate pellicle membrane is to form a cap layer, again transparent to the exposure radiation, directly onto the mask. To be effective, the cap layer would need to be thicker than the depth of focus at mask level. The depth of focus at mask level is given by:

$$DOF = k_2 \cdot \frac{\lambda}{NA^2} \cdot \frac{1}{M^2} \qquad (1)$$

where λ is the wavelength of the EUV radiation, NA the numerical aperture at wafer level, M the magnification of the projection optics and k_2 a constant that is typically near 1. For EUV radiation of 13.5nm, a numerical aperture of 0.25 and a magnification M of 1/5, the depth of focus at mask level is approximately 2.7µm. The effect of such a layer on an EUV projection beam would be excessive. The transmission, T, of radiation through a material with thickness d is given by:

$$T = \exp\left(-\frac{d}{a}\right) \qquad (2)$$

where a is the attenuation length of the material (i.e. the length over which the intensity drops by a factor of 1/e). Even for a material that is relatively transparent to radiation at 13.5nm, the attenuation length is about 0.6µm. Accordingly, a cap layer of thickness 2.7µm would absorb about 99% of all EUV radiation.

It is an object of the present invention to provide a particle shield that is effective in a lithographic projection apparatus using radiation of wavelength less than 200 nm, and especially extreme ultraviolet radiation, to prevent particles reaching the mask or any other component that requires protection from contamination, whilst avoiding unacceptable attenuation of the projection beam.

According to the present invention there is provided a lithographic projection apparatus for imaging a mask pattern in a mask onto a substrate, the apparatus comprising:

an illumination system constructed and arranged to supply a projection beam of radiation;

a first object table constructed to hold a mask;

a second object table constructed to hold a substrate; and

a projection system constructed and arranged to image an irradiated portion of the mask onto a target portion of the substrate; characterized by

particle shield means constructed and arranged to generate an electromagnetic field to deflect particles approaching an object to be shielded.

The particle shield means may generate a substantially uniform (purely) electric field, generally transverse to the direction of particle approaching the shielded object, so as to exert a force on all charged particles that will deflect them away from the object to be shielded. Although such a uniform electric field will not deflect neutral particles, the radiation of the projection beam in a lithographic apparatus, which is the principle source of energy for airborne particles in a lithographic apparatus, is strongly ionizing so that any particles likely to cause problems will almost certainly be charged and will generally have a charge many times the charge of an electron. A substantially uniform electric field can conveniently be generated using a capacitor-like arrangement of conductive plates.

The particle shield may, alternatively or in addition, generate a non-uniform electric field so as to induce a dipole moment in neutral particles and then attract those particles in addition to charged particles. A non-uniform electric field can conveniently be generated using a charged elongate member.

The particle shield may also, again alternatively or in addition to the electric fields, generate a transverse radiation beam, or optical breeze, that will transfer transverse momentum to particles entering the transverse beam and absorbing photons from it. The radiation wavelength can be chosen so as to be absorbed by all expected particles but not expose the resist should any stray radiation reach substrate level.

The particle shield can also be a radiation source directing ionizing radiation, e.g. suitably short wavelength electromagnetic radiation or an electron beam, across the front of the

object to be shielded. With such an arrangement the object to be shielded can be charged positively, to repel positively-charged ions, compared to its surroundings, and/or relatively negative collection plates can be provided to attract positively-charged ions. This arrangement ensures protection of the object to be shielded even when the main projection beam is off.

The object to be shielded is preferably a mask, since particles adhering to the mask are most detrimental to the quality of the projected image, but may also be a mirror or other element in the illumination or projection systems. Particles incident on, and possibly chemically reacting with, such elements may cause a loss in the reflectivity and therefore errors in the illumination dose received at the substrate.

By using electromagnetic fields rather than a physical barrier, the particle shield of the present invention performs its function without any attenuation of the projection beam.

The present invention also provides a device manufacturing method using a lithography apparatus comprising:

an illumination system constructed and arranged to supply a projection beam of radiation;

a first object table constructed to hold a mask;

a second object table constructed to hold a substrate; and

a projection system constructed and arranged to image an irradiated portion of the mask onto target portions of the substrate; the method comprising the steps of:

providing a mask containing a pattern to said first object table;

providing a substrate which is at least partially covered by a layer of radiation-sensitive material to said second object table;

irradiating portions of the mask and imaging said irradiated portions of said mask onto said target portions of said substrate; characterized by the step of:

generating an electromagnetic field in the vicinity of an object to be shielded to deflect particles approaching said object to be shielded.

In a manufacturing process using a lithographic projection apparatus according to the invention a pattern in a mask is imaged onto a substrate which is at least partially covered by a layer of radiation-sensitive material (resist). Prior to this imaging step, the substrate may undergo various procedures, such as priming, resist coating and a soft bake. After exposure, the substrate may be subjected to other procedures, such as a post-exposure bake (PEB), development, a hard bake and measurement/inspection of the imaged features. This array of procedures is used as a basis to pattern an individual layer of a device, e.g. an IC. Such a patterned layer may then undergo various processes such as etching, ion-implantation (doping), metallization, oxidation, chemo-mechanical polishing, etc., all intended to finish off an individual layer. If several layers

are required, then the whole procedure, or a variant thereof, will have to be repeated for each new layer. Eventually, an array of devices will be present on the substrate (wafer). These devices are then separated from one another by a technique such as dicing or sawing, whence the individual devices can be mounted on a carrier, connected to pins, etc. Further information regarding such processes can be obtained, for example, from the book "Microchip Fabrication: A Practical Guide to Semiconductor Processing", Third Edition, by Peter van Zant, McGraw Hill Publishing Co., 1997, ISBN 0-07-067250-4.

Although specific reference may be made in this text to the use of the apparatus according to the invention in the manufacture of ICs, it should be explicitly understood that such an apparatus has many other possible applications. For example, it may be employed in the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, liquid-crystal display panels, thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms "reticle", "wafer" or "die" in this text should be considered as being replaced by the more general terms "mask", "substrate" and "target area" or "exposure area", respectively.

The present invention and its attendant advantages will be described below with reference to exemplary embodiments and the accompanying schematic drawings, in which:

Fig. 1 depicts a lithographic projection apparatus according to a first embodiment of the invention;

Fig. 2 is a diagram of a particle shield in the first embodiment of the present invention;

Fig. 3 is a diagram of a particle shield in a second embodiment of the present invention;

Fig. 4 is a diagram showing the induced dipole moment in a neutral particle;

Fig. 5 is a diagram of a particle shield in a third embodiment of the present invention;

Fig. 6 is a diagram of a particle shield in a fourth embodiment of the present invention;

Fig. 7 is a diagram of a particle shield in a fifth embodiment of the present invention; and

Fig. 8 is a diagram of a particle shield in a sixth embodiment of the present invention.

In the various drawings, like parts are indicated by like references.

Embodiment 1

Figure 1 schematically depicts a lithographic projection apparatus 1 according to the invention. The apparatus comprises:

- a radiation system LA, IL for supplying a projection beam PB of EUV radiation;
- a first object table (mask table) MT provided with a first object (mask) holder for holding a mask MA (e.g. a reticle), and connected to first positioning means PM for accurately positioning the mask with respect to item PL;
- a second object table (substrate table) WT provided with a second object (substrate) holder for holding a substrate W (e.g. a resist-coated silicon wafer), and connected to second positioning means PW for accurately positioning the substrate with respect to item PL;
- a projection system ("lens") PL (e.g. a refractive, catadioptric or reflective system) for imaging an irradiated portion of the mask MA onto a target portion C (die) of the substrate W.

As here depicted, the apparatus is of a reflective type (i.e. has a reflective mask). However, in general, it may also be of a transmissive type, for example.

The radiation system comprises a source LA (e.g. an undulator or wiggler provided around the path of an electron beam in a storage ring or synchrotron or a plasma source) which produces a beam of radiation. This beam is passed along various optical components included in illumination system ("lens") IL so that the resultant beam PB is collected in such a way as to give illumination of the desired shape and intensity distribution at the entrance pupil of the projection system and the mask.

The beam PB subsequently impinges upon the mask MA which is held in the mask holder on the mask table MT. Having been selectively reflected by the mask MA, the beam PB passes through the lens PL, which focuses the beam PB onto a target area C of the substrate W. With the aid of the interferometric displacement measuring means IF and positioning means PW, the substrate table WT can be moved accurately, e.g. so as to position different target areas C in the path of the beam PB. Similarly, the positioning means PM and interferometric displacement measuring means IF can be used to accurately position the mask MA with respect to the path of the beam PB. In general, movement of the object tables MT, WT will be realized with the aid of a long stroke module (course positioning) and a short stroke module (fine positioning), which are not explicitly depicted in Figure 1.

The depicted apparatus can be used in two different modes:

1. In step mode, the mask table MT is kept essentially stationary, and an entire mask image is projected in one go (i.e. a single "flash") onto a target area C. The substrate table WT is then shifted in the X and/or Y directions so that a different target area C can be irradiated by the beam PB;

2. In scan mode, essentially the same scenario applies, except that a given target area C is not exposed in a single "flash". Instead, the mask table MT is movable in a given direction (the so-called "scan direction", e.g. the Y direction) with a speed v, so that the projection beam PB is caused to scan over a mask image; concurrently, the substrate table WT is simultaneously moved in the same or opposite direction at a speed V = Mv, in which M is the magnification of the lens PL (typically, M = 1/4 or 1/5). In this manner, a relatively large target area C can be exposed, without having to compromise on resolution.

Figure 2 shows an electrostatic particle shield 10 provided in the vicinity of mask MA. The particle shield 10 of the invention is attached to the mask holder or mask table MT, rather than the mask itself as are conventional pellicles. It will be seen that the mask MA is reflective and disposed generally horizontally with the reflecting surface facing downward. The incident projection beam PBi is directed from the illumination system IL generally upwardly onto the mask MA and the reflected projection beam PBr is then reflected downwards to the projection system PL. As the operative surface of the mask faces downwards, gravity will tend to keep particles present in the apparatus away from the mask. However the powerful EUV projection beam provides energy to particles in its path which can enable them to overcome gravity. In particular, photons in the incident projection beam PBi colliding with particles will impart a generally upward momentum. Thus, contaminant particles can be driven towards the mask MA where they will cause undesirable contamination. Moving parts of the apparatus can also both create contaminant particles and provide transport energy to overcome gravity.

To prevent this, the electrostatic particle shield 10 comprises two capacitor-like plates 11, 12 placed perpendicular to the mask on either side of it. The plates 11, 12 are oppositely-charged so as to establish an electric field E between them. Assuming that the area of the plates 11, 12 is substantially greater than their separation, d, the electric field, E, is given by:

$$E = \frac{V}{d} \qquad (3)$$

where V is the voltage across the capacitor. In an embodiment of the present invention, the separation, d, may be about 300mm, approximately twice the width of a mask, and the potential difference between plates 11, 12 may be about 10kV. This gives an electric field of 33kV/m.

The force exerted on a charged particle in the electric field between capacitor plates 11, 12, is equal to the product of the charge on the particle and the electric field strength, E. In an operating lithographic apparatus using EUV exposure radiation it can be assumed that any particle entering the projection beam will become rapidly ionized. The energy of an EUV photon

is 92eV compared to an ionization energy of the order of only a few eV's. A particle of 20nm diameter in a projection beam having a typical power density of $8kW/m^2$ will be impacted by about 1.7×10^5 photons per second and will thus very likely be multiply ionized. For a singly ionized particle, the worst case, the force exerted on the particle will be about 5.3×10^{-15} N. It can be shown that this force is sufficient to prevent such particles reaching the mask. The time, t, taken for a particle to move from one capacitor plate to the other, the worst-case situation, is given by:

$$t = \sqrt{\frac{2dm}{F}} \tag{4}$$

where m is the mass of the particle and F the electrical force. Table 1 below gives the transit time for various different sizes of particle, assuming a spherical particle having a density ρ equal to $2000kg/m^3$.

particle size	time
20nm	0.1ms
100nm	11ms
500nm	0.11s
1μm	0.35s

In the worst case, a particle ejected from a metal part in the apparatus, e.g. following a collision, could be moving at maximum at the speed of sound in the metal, e.g. about 5,000m/s. A particle of 20nm diameter moving at this speed through the capacitor will be deflected if the height, h, of the capacitor plates 11, 12 is about 500mm. This is the case even if the particle is only minimally-charged. It should also be noted that, due to their substantially higher charge-to-mass ratios, any ions or charged molecules will be very quickly deflected by the electrostatic particle shield 10.

Embodiment 2

A second embodiment of the present invention, which may be the same as the first embodiment save as described below, includes an electrostatic particle shield 20 making use of a non-uniform electric field.

The electrostatic particle shield 20 of the second embodiment of the invention is shown in Figure 3. An elongate charged member 21 is placed perpendicular to and to one side of the mask MA, adjacent the volume traversed by the incident and reflected projection beams PBi, PBr. A single charged member, as opposed to a pair of charged plated forming a capacitor, forms a non-uniform electric field which induces a dipole in neutral molecules and particles and then exerts a force on the dipole. A non-uniform electric field will also exert a force on polar molecules and so will capture these as well as neutral molecules or particles in which a dipole moment is induced. The force exerted on a dipole is given by:

$$\vec{F} = (\vec{p}.\vec{\nabla})\vec{E} \tag{5}$$

where p is the induced dipole moment of the particle. The elongate charged member 21 can be approximated as a cylinder with a charge per unit length of the cylinder of μ Coulomb/m. This will induce an electric field given by:

$$E(\vec{r}) = \frac{\mu}{2\pi\varepsilon_0 r} \tag{6}$$

where $\vec{r}$ is a position vector in an arbitrary coordinate system, r is the distance to the center of the cylinder, and ε_0 is the dielectric constant in vacuum. The electric field inside a sphere with dielectric constant ε is given by:

$$E_{particle}(\vec{r}) = \frac{3}{\varepsilon + 2} E(\vec{r}), \tag{7}$$

whilst the electric field that is induced by displaced charges inside the particle is given by:

$$E_{induced}(\vec{r}) = -\frac{\varepsilon - 1}{\varepsilon + 2} E(\vec{r}). \tag{8}$$

The polarization P is defined as the dipole moment per unit volume and given by:

$$P = \varepsilon_0(\varepsilon - 1)E_{particle} = \frac{\varepsilon - 1}{\varepsilon + 2} 3\varepsilon_0 E(r), \tag{9}$$

for a particle at a distance r from the center of the charged cylinder so that the particle having a radius r_p can be replaced by a dipole with a moment, p, given by:

$$p=\frac{\varepsilon-1}{\varepsilon+2}4\pi\varepsilon_0 r_p^3 E(r). \qquad (10)$$

The particle can thus be regarded as charges +Q, -Q separated by twice the radius r_p of the particle, as shown in Figure 4. The magnitude of the charges Q is given by:

$$Q=\frac{\varepsilon-1}{\varepsilon+2}2\pi\varepsilon_0 r_p^2 E(r)=\frac{\varepsilon-1}{\varepsilon+2}\frac{r_p^2\mu}{r}. \qquad (11)$$

From this, the force on the dipole can be expressed as:

$$F=QE(r-r_p)-QE(r+r_p)=\frac{Q\mu}{2\pi\varepsilon_0(r-r_p)}-\frac{Q\mu}{2\pi\varepsilon_0(r+r_p)} \qquad (12)$$

which can be approximated, when the particle radius is small compared to the distance from the elongate charge member 21, as:

$$F\cong\frac{Q\mu}{2\pi\varepsilon_0 r}.\frac{2r_p}{r}=\frac{Q\mu r_p}{\pi\varepsilon_0 r^2}=\frac{\varepsilon-1}{\varepsilon+2}.\frac{\mu^2 r_p^3}{\pi\varepsilon_0 r^3}. \qquad (13)$$

Because this force is dependent on the cube of the particle radius, the acceleration experienced by particles is independent of size. For a particle of density, ϱ, equal to 2000 kg/m^3 and a charge density, μ, of 10^{-7} Coulomb/m, the time to travel over a distance of about 150 mm, the size of a mask, for different dielectric constants, ε, is given in Table 2 below:

ε	time (s)
2	224
3	177
5	158
∞ (metal particles)	112

Although it does take a significant time for the particles to reach the charged member 21, the non-uniform field will effectively capture neutral particles in the apparatus since the non-uniform field can be arranged to extend for a distance several times the mask width in front of the mask, allowing plenty of time for the particles to be deflected.

Embodiment 3

A third embodiment of the present invention, which may be the same as the first or second embodiment save as described below, employs an optical particle shield which creates an optical breeze to deflect contaminant particles.

The third embodiment is shown in Figure 5 and comprises radiation source 31 which emits high-intensity shielding beams 32 of electromagnetic radiation parallel to the mask MA and across the space in front of it. The radiation source 31 can be any suitable source, or array of sources, with appropriate collimating and/or directing means to direct the beam across the required space whilst minimizing generation of stray light outside the desired area. A beam absorber 33 may be placed the other side of the space in front of the mask MA to absorb the shielding radiation and prevent reflections. The photons of the shielding beams 32 carry momentum m_r which will be transferred to any particle that absorbs photons from the beams 32. The wavelength of the light in the particle shield 30 is therefore chosen to be absorbed by all particles expected. The wavelength may also be chosen as one to which the resist used is not sensitive so that any stray light that does reach the substrate does not expose the resist.

The pressure exerted by a radiation beam of intensity I per m^2 is given by:

$$P_{BEAM} = \frac{I}{c} \tag{14}$$

where c is the velocity of light (3×10^8 m/s). The acceleration of a spherical particle with radius r_p and density ρ is given by:

$$a_{breeze} = \frac{3I}{4 c r_p \rho} \tag{15}$$

which is constant with time so that the time required to travel over a distance d is given by:

$$t = \sqrt{\frac{2d}{a_{breeze}}} = \sqrt{\frac{8 d c r_p \rho}{3I}} \tag{16}$$

The time taken for particles of various sizes to travel over a distance of 150mm, the approximate size of a mask, are given in Table 3 below, assuming a particle density, ρ, of 2000kg/m^3 and an intensity of 8kW/m^2.

particle size (nm)	time (s)
10	0.4
25	0.6
50	0.9
100	1.8

Again, if the optical particle shield 30 is arranged to extend over a substantial distance in front of the mask MA, a significant deflection can be achieved. In particular, the optical particle shield can be arranged to have a similar radiation intensity to the projection beam PB so that the deflection force exerted by the optical shield is comparable to the force exerted by the projection beam tending to lift the particles towards the mask MA.

Embodiment 4

In a fourth embodiment, which may be the same as the first to third embodiments save as described below, additional ionizing radiation is provided in front of the element to be protected which is itself charged to repel ions approaching it.

Figure 6 shows ionizing radiation source 41 which directs a transverse beam 42 of ionizing radiation across the region in front of the element to be protected, in this case mask MA. The beam 42 has a thickness, t, perpendicular to the functional surface of the mask MA that is sufficiently large to ensure ionization, preferably multiple ionization, of most or all atoms approaching the mask MA. The wavelength of the radiation should be short (energetic) enough to ensure ionization of all atoms expected, and thus should preferably be shorter than 200nm (6.2 eV). For example, an He discharge lamp emitting 59nm radiation (21 eV) is suitable. Such sources are generally pulsed and in that case should have a repetition rate fast enough to irradiate all atoms passing through the protective region. For example, a repetition rate of 4 kHz may be used with a beam width of 100mm. A gas molecule moving at 400ms^{-1}, a typical speed at room temperature, will traverse the shield in a minimum of 0.25ms and thus will be illuminated by at least one pulse.

Embodiment 5

The fifth embodiment, shown in Figure 7, is a variant of the fourth embodiment. In the fifth embodiment, collector plates 43 which are negatively-charged relative to the mask MA are added to increase the shielding effect. The collector plates 43 are situated on the other side of the protective beam 42 than the mask MA and serve to attract the positively-charged ions repelled by the relatively positive mask MA.

Embodiment 6

The sixth embodiment, shown in Figure 8, is a variant of the fifth embodiment but relies on the projection beam PB to ionize any contaminants approaching the mask MA. In this embodiment the collector shield 43 can be positioned closer to the mask and the path of the projection beam PB.

Whilst we have described above specific embodiments of the invention it will be appreciated that the invention may be practiced otherwise than described. The description is not intended to limit the invention. In particular, it will be appreciated that the particle shields of the different embodiments may be combined so that a particle shield according to the invention may make use of any one or more of: a uniform electric field, a non-uniform electric field, an optical breeze, ionizing radiation and charging of the object to be shielded. The invention can be used in lithography apparatus using any form of projection beam, especially but not exclusively, 193nm, 157nm or EUV.

CLAIMS

1. A lithographic projection apparatus for imaging a mask pattern in a mask onto a substrate, the apparatus comprising:

an illumination system constructed and arranged to supply a projection beam of radiation;

a first object table constructed to hold a mask;

a second object table constructed to hold a substrate; and

a projection system constructed and arranged to image an irradiated portion of the mask onto a target portion of the substrate; characterized by

particle shield means constructed and arranged to generate an electromagnetic field to deflect particles approaching an object to be shielded.

2. Apparatus according to claim 1 wherein said particle shield means is adapted to generate a substantially uniform electric field in the vicinity of said object to be shielded.

3. Apparatus according to claim 2 wherein said particle shield means comprises a pair of conductive plates arranged substantially parallel to each other on either side of a region adjacent said object to be shielded and means for establishing a potential difference between said pair of conductive plates.

4. Apparatus according to claim 1, 2 or 3 wherein said particle shield means is adapted to generate a non-uniform electric field in the vicinity of said object to be shielded.

5. Apparatus according to claim 4 wherein said particle shield means comprises an elongate charged member.

6. Apparatus according to any one of the preceding claims wherein said particle shield means comprises a radiation source arranged to generate a beam of radiation in the vicinity of said object to be shielded.

7. Apparatus according to claim 6 wherein said radiation source is adapted to generate an electromagnetic beam effective as an optical breeze to deflect particles by momentum transfer.

8. Apparatus according to claim 6 or 7 wherein said radiation source is adapted to generate a beam of radiation capable of ionizing particles approaching said object to be shielded.

9. Apparatus according to claim 6, 7 or 8 wherein said radiation source is adapted to direct said beam of radiation in a direction substantially parallel to said object to be shielded.

10. Apparatus according to any one of the preceding claims wherein said particle shield means comprises means for charging said object to be shielded to a positive potential relative to its surroundings.

11. Apparatus according to any one of the preceding claims wherein said particle shield means comprises collector plates positioned near said object to be shielded and means for charging said collector plates to a negative potential relative to said object to be shielded.

12. Apparatus according to any one of the preceding claims wherein said object to be shielded is a mask held on said first object table.

13. Apparatus according to claim 12 wherein said particle shield means is mounted to said first object table.

14. Apparatus according to any one of claims 1 to 11, wherein said object to be shielded is a mirror or other element comprised in the illumination or projection system.

15. Apparatus according to any one of the preceding claims wherein said projection beam comprises ultraviolet radiation having a wavelength less than about 200nm.

16. Apparatus according to claims 1 to 14 wherein said projection beam comprises extreme ultraviolet radiation, e.g. having a wavelength in the range of from 8 to 20nm, especially 9 to 16nm.

17. A device manufacturing method using a lithography apparatus comprising:

an illumination system constructed and arranged to supply a projection beam of radiation;

a first object table constructed to hold a mask;

a second object table constructed to hold a substrate; and

a projection system constructed and arranged to image an irradiated portion of the mask onto target portions of the substrate; the method comprising the steps of:

providing a mask containing a pattern to said first object table;

providing a substrate which is at least partially covered by a layer of radiation-sensitive material to said second object table;

irradiating portions of the mask and imaging said irradiated portions of said mask onto said target portions of said substrate; characterized by the step of:

generating an electromagnetic field in the vicinity of an object to be shielded to deflect particles approaching said object to be shielded.

18. A device manufactured in accordance with the method of claim 17.

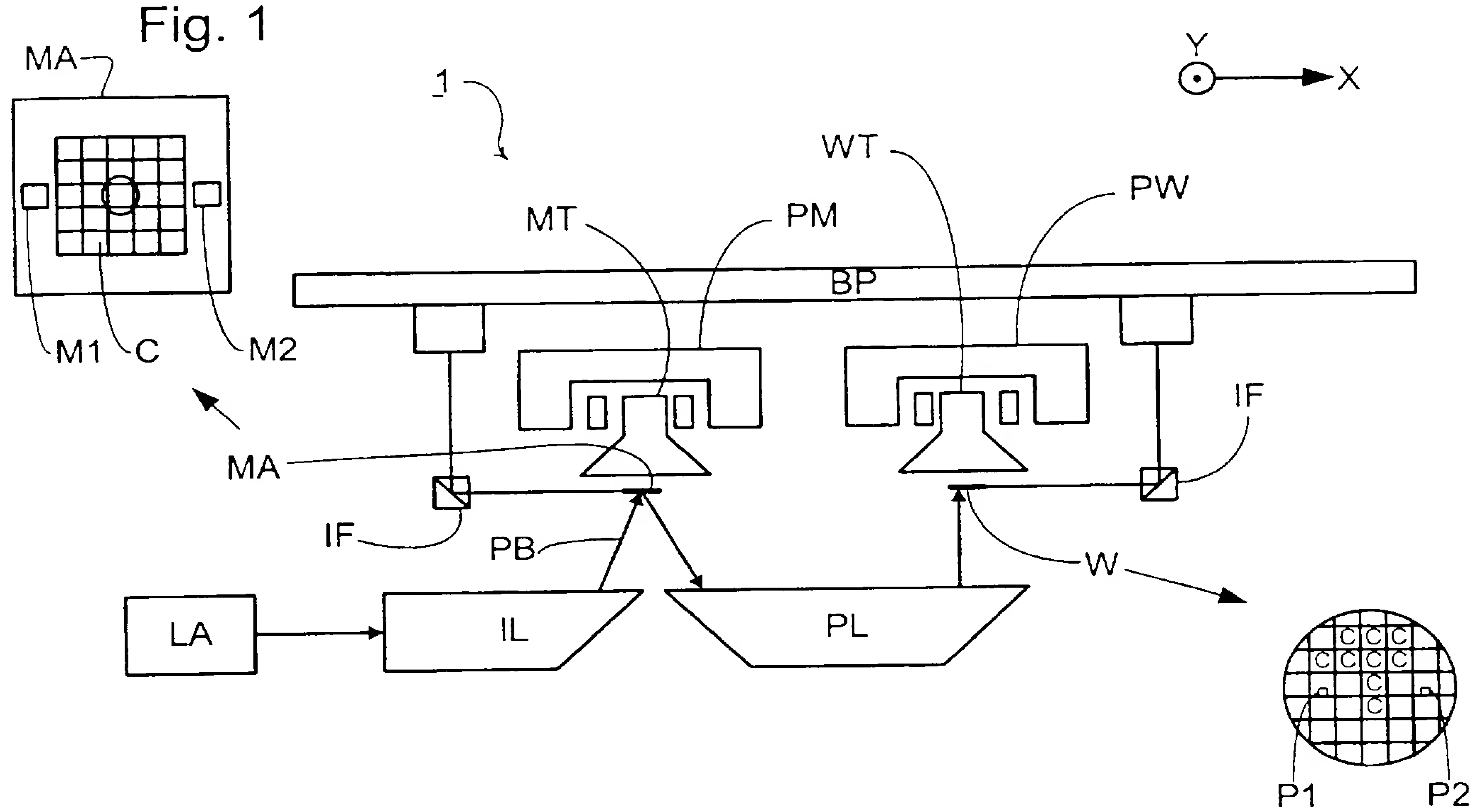
ABSTRACT

PARTICLE SHIELDS FOR USE
IN LITHOGRAPHIC PROJECTION APPARATUS

In a lithographic projection apparatus, an object such as a mask is shielded from stray particles by a particle shield using electromagnetic fields. The fields may be a uniform electric field, a non-uniform electric field or an optical breeze. The particle shield means are fixed to the mask holder rather than the mask.

Fig. 2

Fig. 1


MA
1
Y
X
WT
PW
MT
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C
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P2

Fig. 2

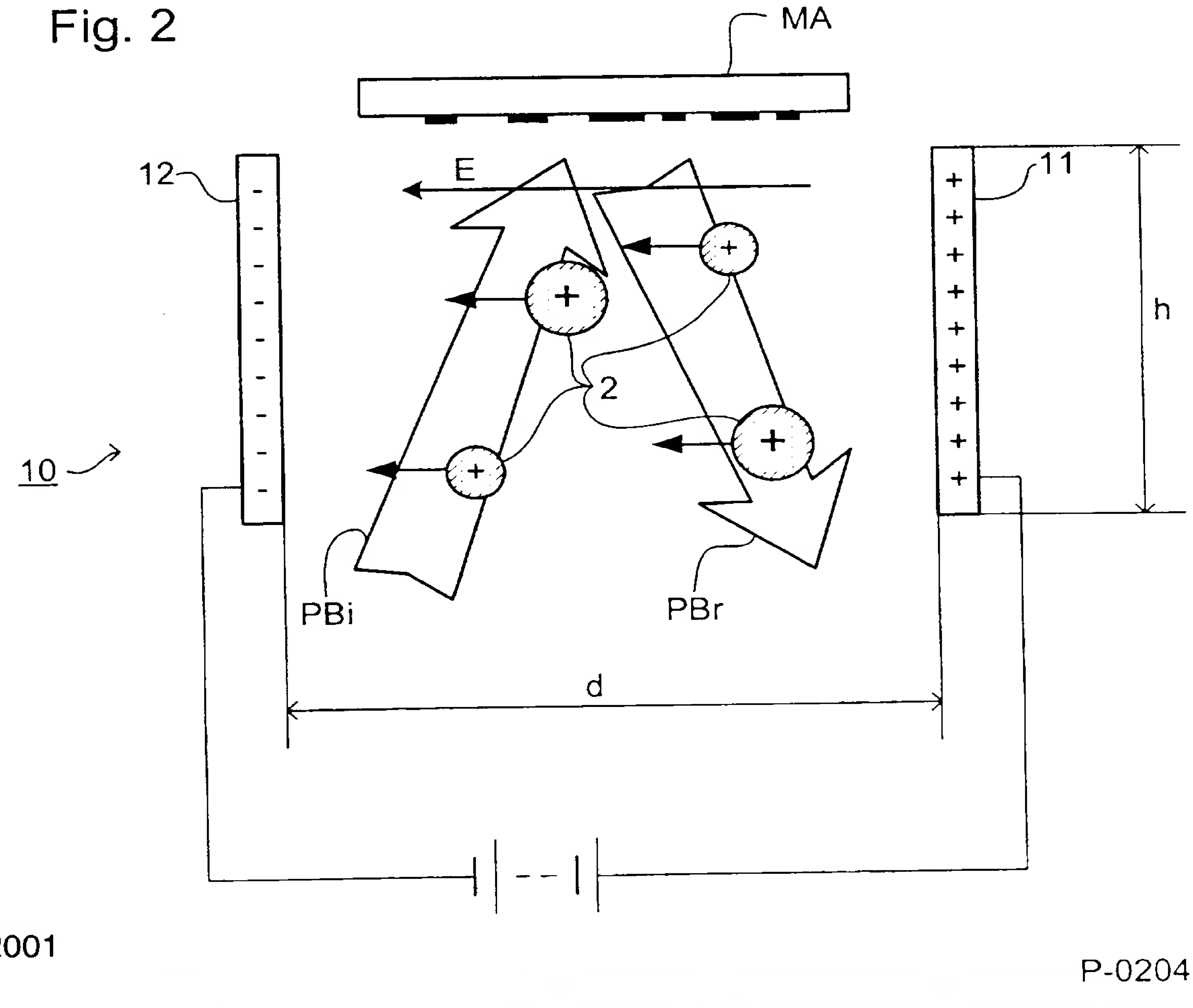
MA
12
E
11
h
2
10
PBi
PBr
d

Fig. 3

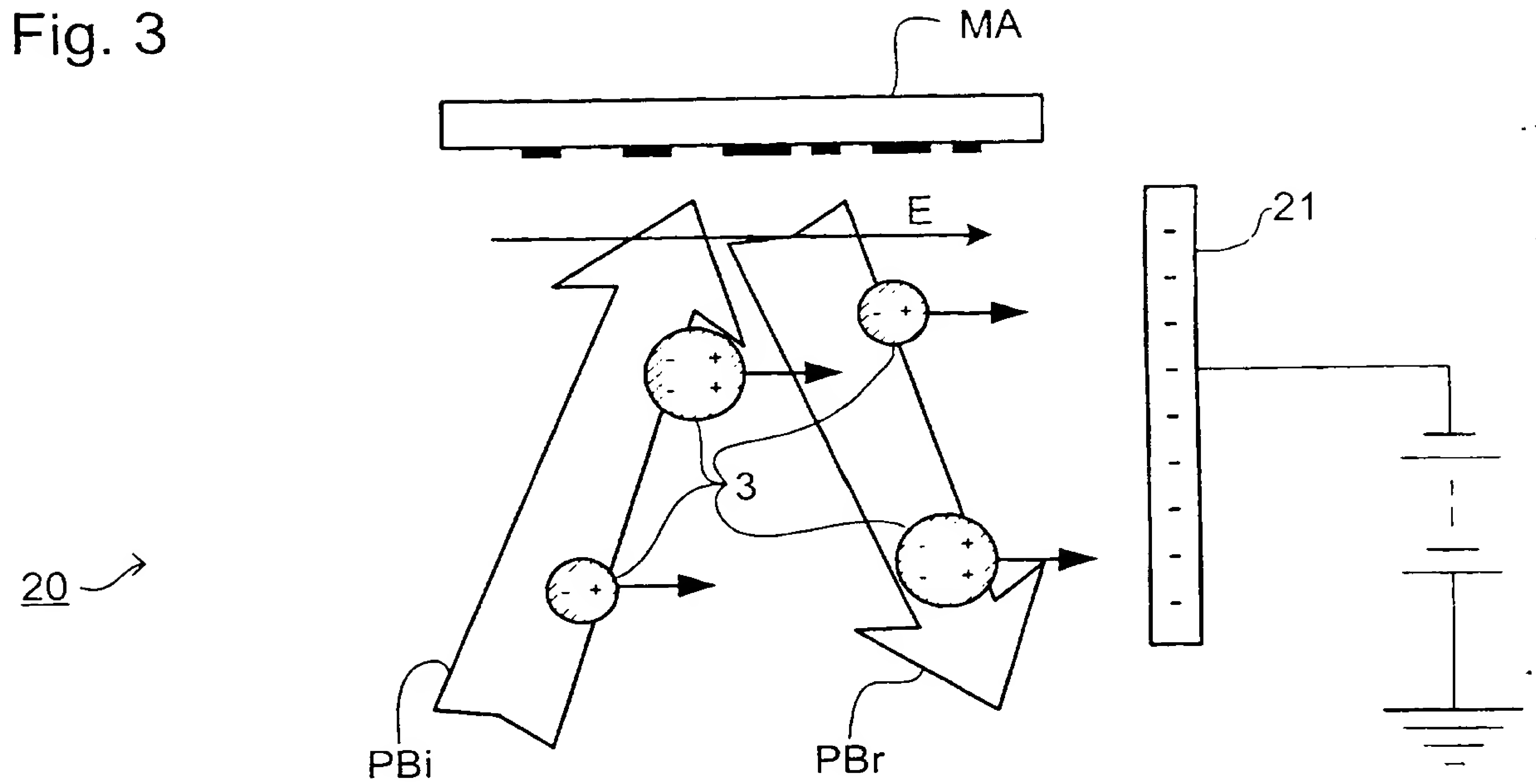

Fig. 4

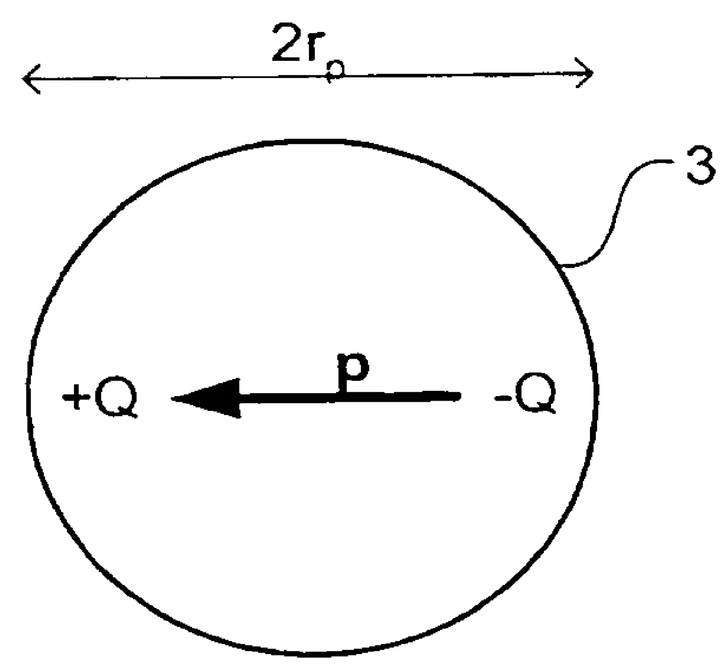

Fig. 5

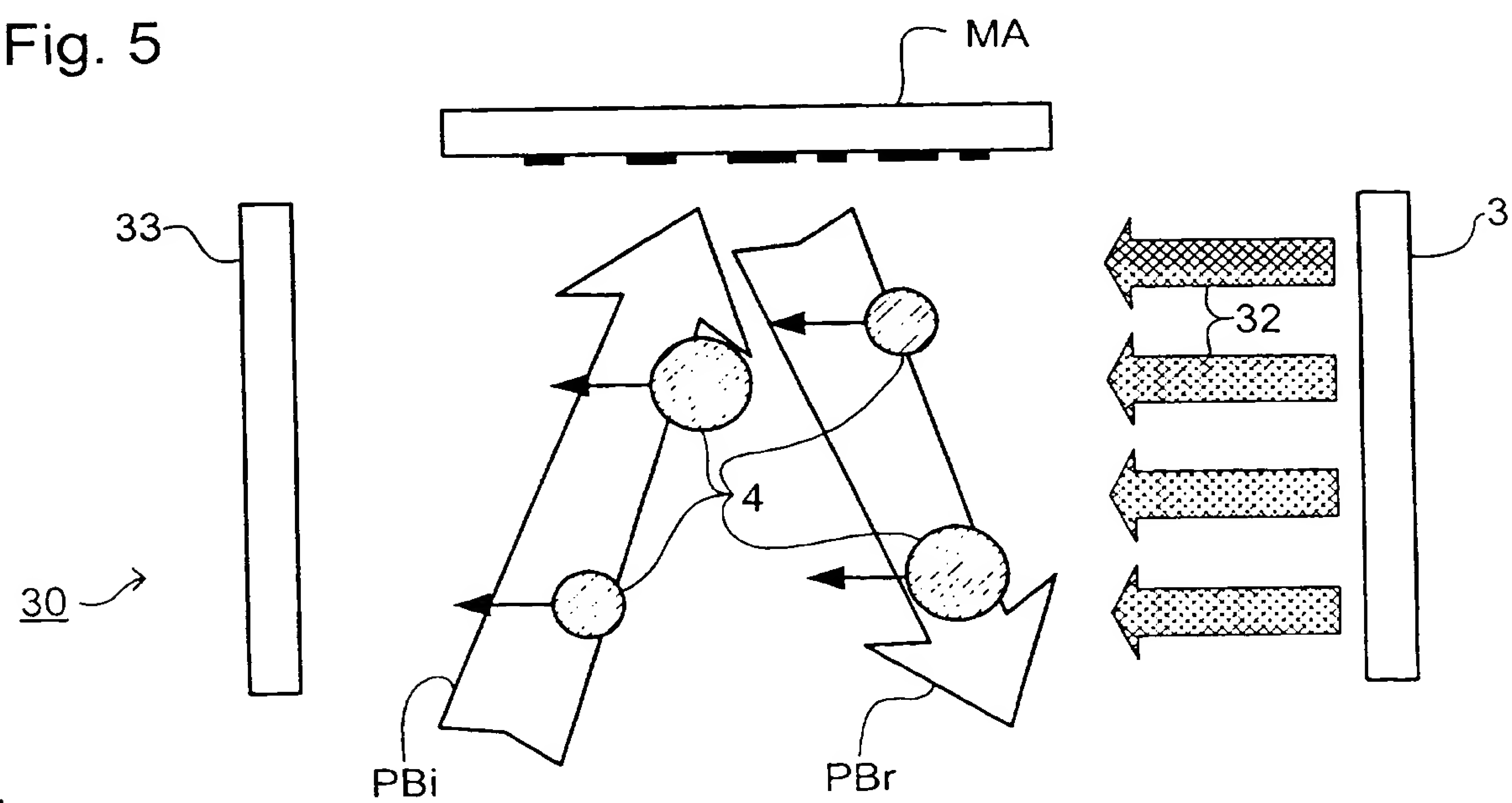

Fig. 6

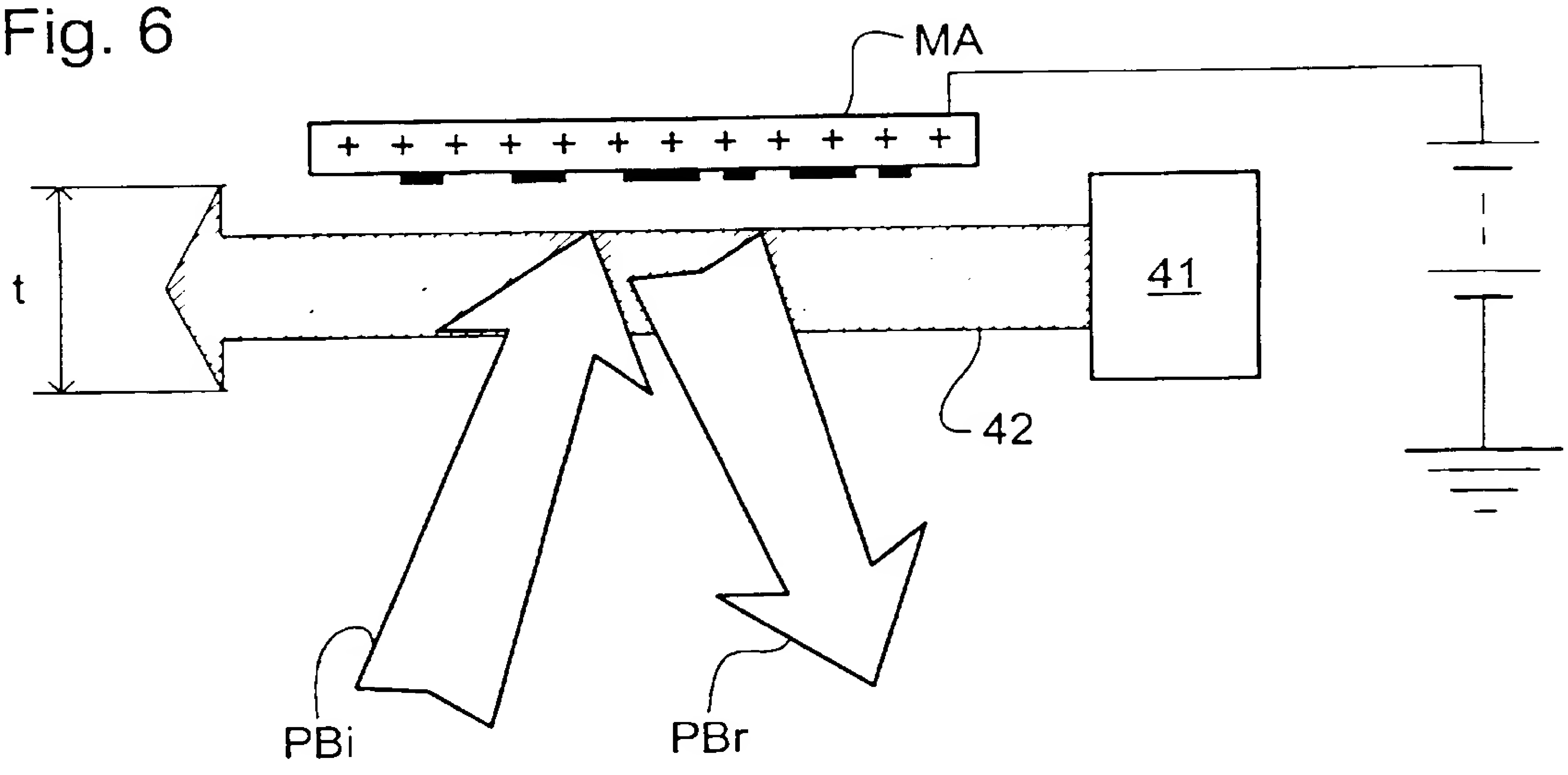

Fig. 7

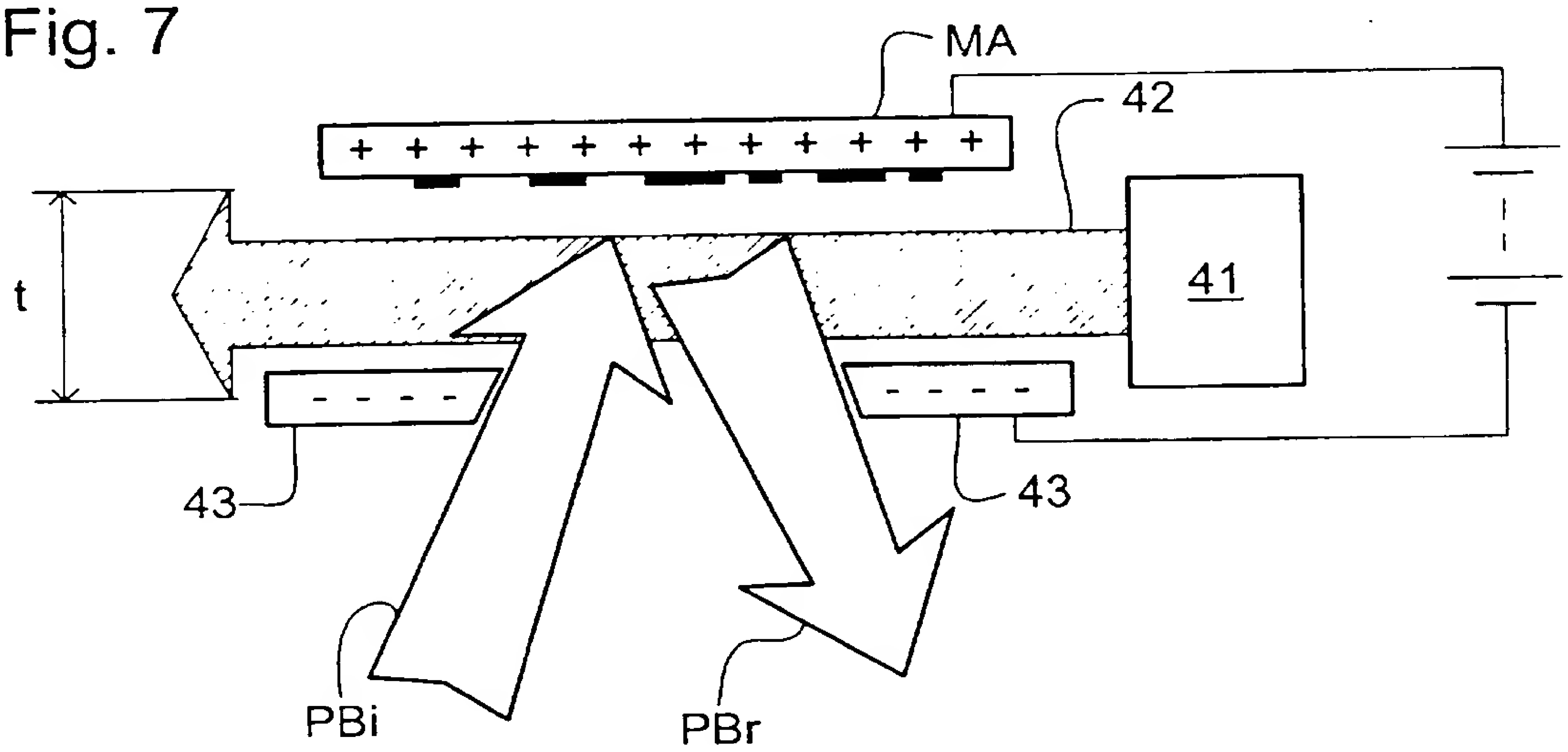

Fig. 8